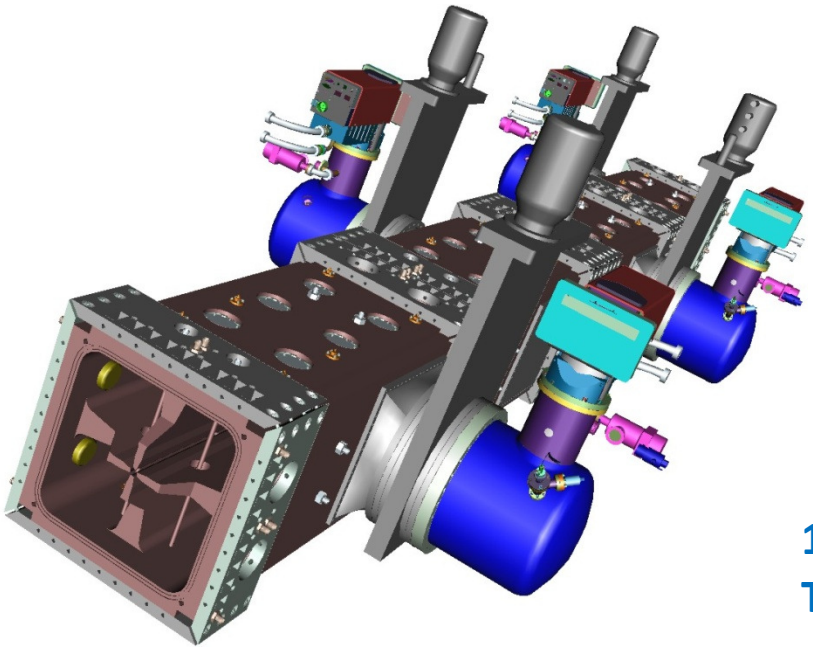
Couplers for PXIE RFQ

S. Kazakov

10/23/2012



5mA H-, 30 kV -> 2.1 MV

10.5 kW beam, 12% loading
Total RF power ~ 90 kW

Requirements:

- F = 162.5
- Two couplers , ~50 kW CW each, (75 kW)
- Input port ~ 3’’
- Inductive coupling (loop)

Expected problems:

- Loop heating – cooling is required
- Multipactor – measures to suppress required
- Thermal and mechanical stress at ceramic – proper design

Possible measures to multipactor suppressing:

- Magnetic field
- TiN coating
- Special profile of surface (grooved)
- HV bias

Magnetic field:
Can be applied almost to any coupler and any time
(just put a coil around coupler).
But can not be applied to part of coupler inside RFQ coupler.
Multifactor is possible inside loop.

Coating:
Can be applied to any coupler and does not require special design.

Grooving:
Hard to image all surfaces are grooved (loop).
It requires additional investigation (simulations).
Requires special design (with grooves)

HV bias.
Requires special design.

We chose a HV bias.

- **We have a simple design solution from PX couplers.**
  It is compatible with cooling system.

- **In simulation a HV bias suppresses MP well including loop area.**

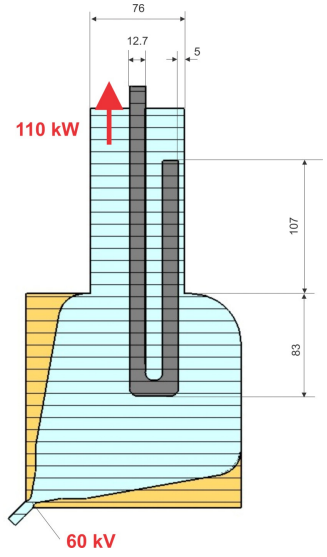
- **Magnetic field and TiN are backup measures.**

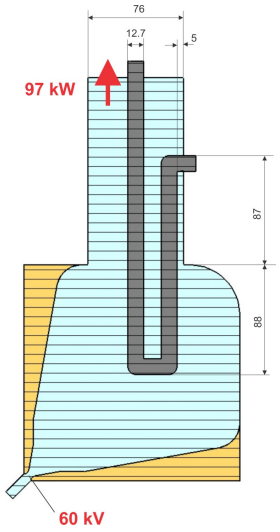
HV bias requires:

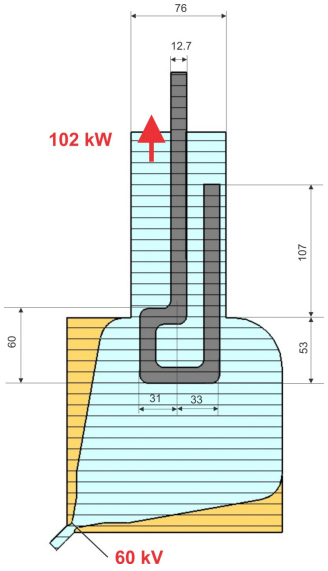
- **Not grounded loop**

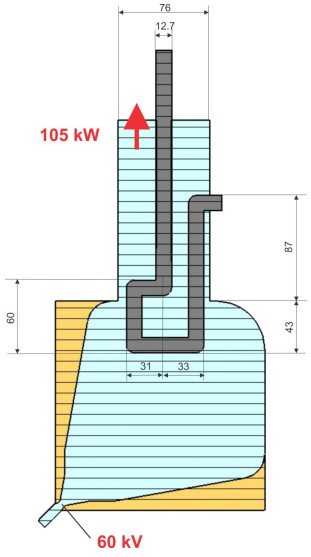
- **Air loop cooling (water under HV?).**
  (Air cooling is preferable in term of system safety –
  water leak in vacuum is more dangers then air leak)

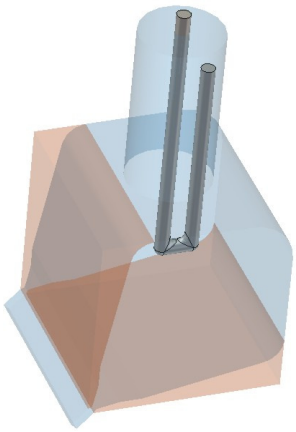
Loop

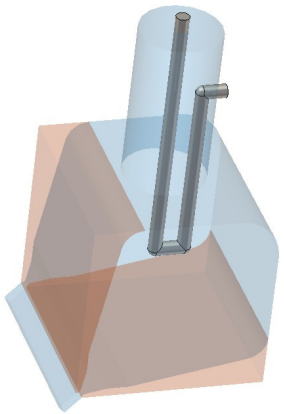


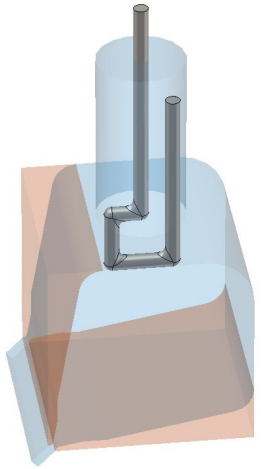


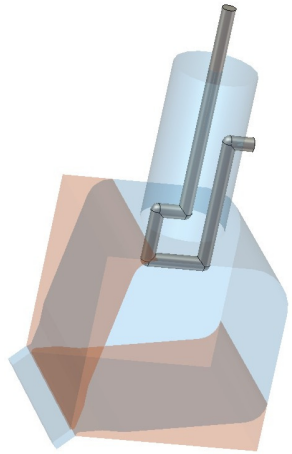






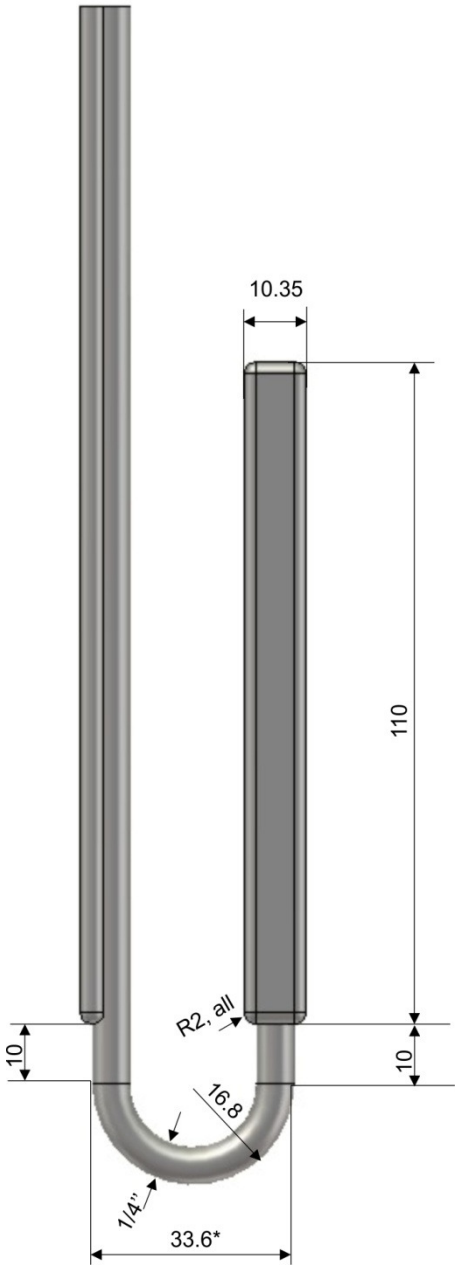


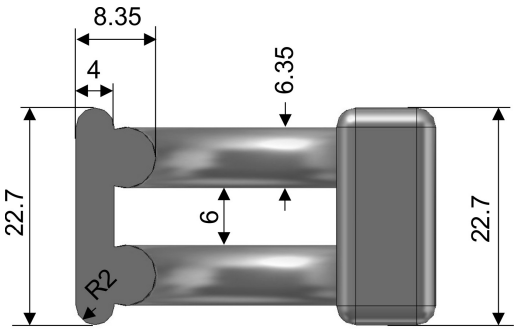




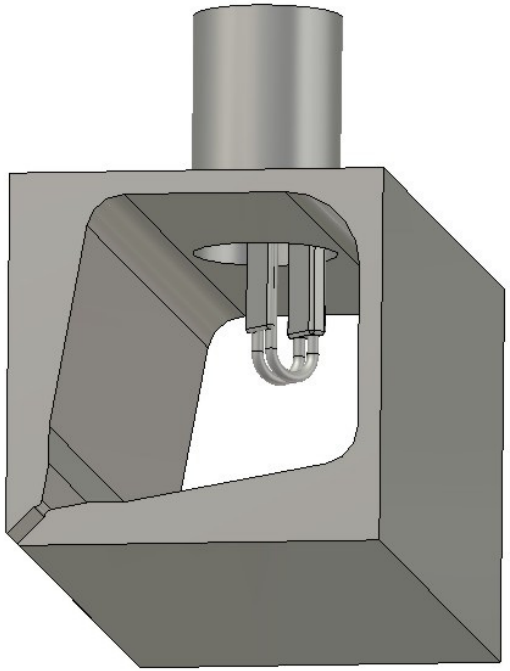
There is no big difference between grounded and not grounded loops: approximately the same penetrations and the same heating

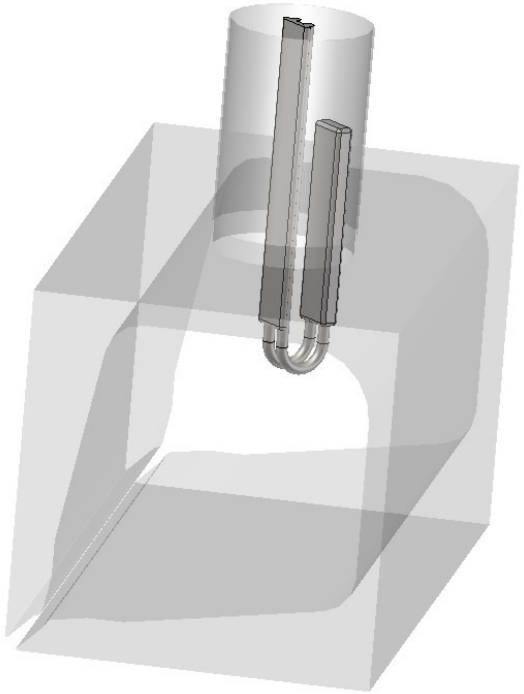
Chosen loop shape

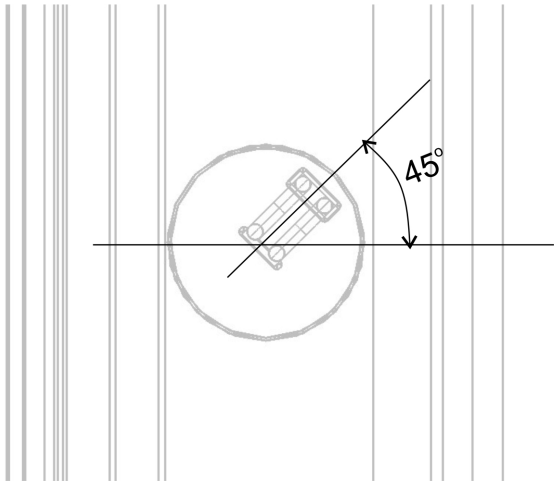


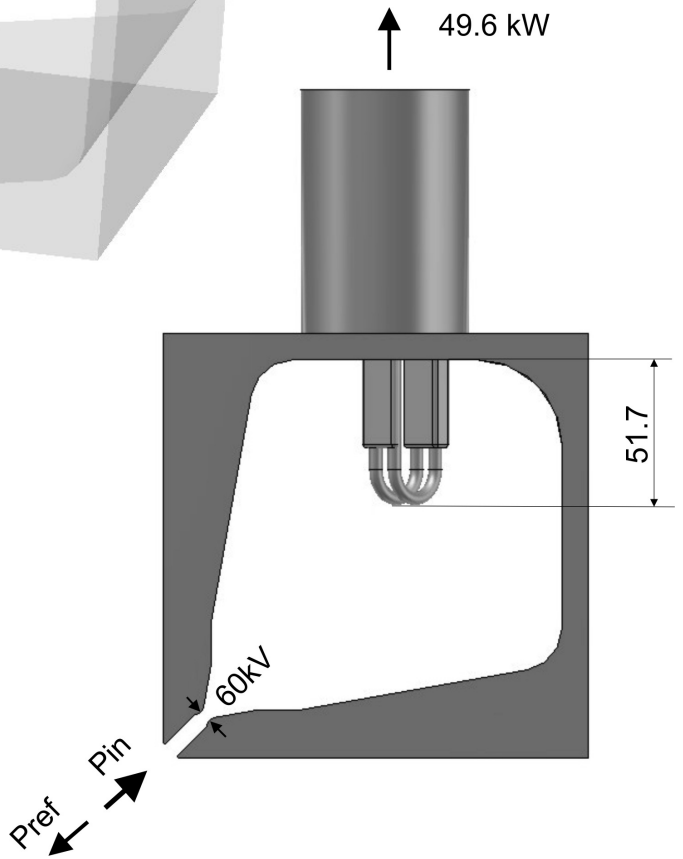


Loop penetration



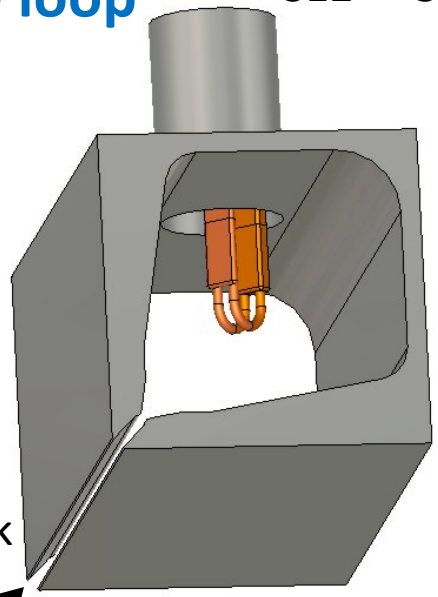






Loss in the loop

S12 = -30.925dB



Pin = 1 W peak

RF loss at loop surface:

Q-Factor Calculation

H-Field data: 2D/3D Results\H-Field\h-field (f=162.5) [1]

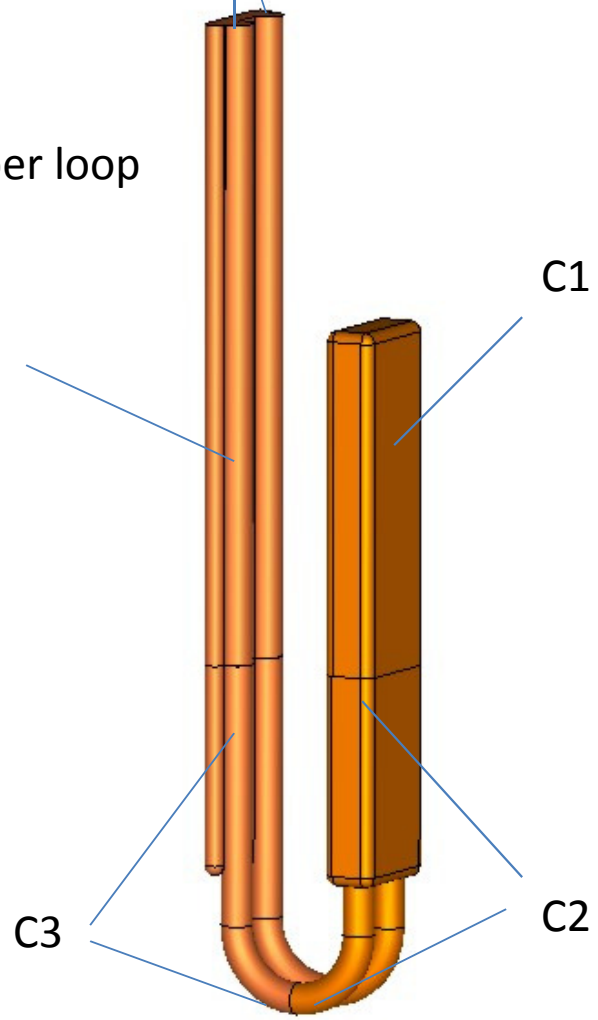
Calculate | Specials... | Export... | Close | Help

Material/Solid	Conductivity	Mue	Loss/W(peak)	Loss/%	Q
Cond. Enclosure	5.8000e+007	1	0.0000e+000	0	
PEC	5.8000e+007	1	2.3812e-005	93.3	2.1115e+004
C1	5.8000e+007	1	1.2934e-007	0.507	3.8874e+006
C2	5.8000e+007	1	7.8895e-007	3.09	6.3728e+005
C4	5.8000e+007	1	1.4339e-007	0.562	3.5064e+006
C3	5.8000e+007	1	6.5035e-007	2.55	7.7309e+005
Sum			2.5524e-005		1.9699e+004

Modify... | Modify All... | Hide / Unhide | Hide/Unh. All

Diameter of air channels are 4.75mm

Copper loop



RF loss at surface loop:

C1 -68.883 dB
C2 -61.030 dB
C3 -61.869 dB
C4 -68.435 dB

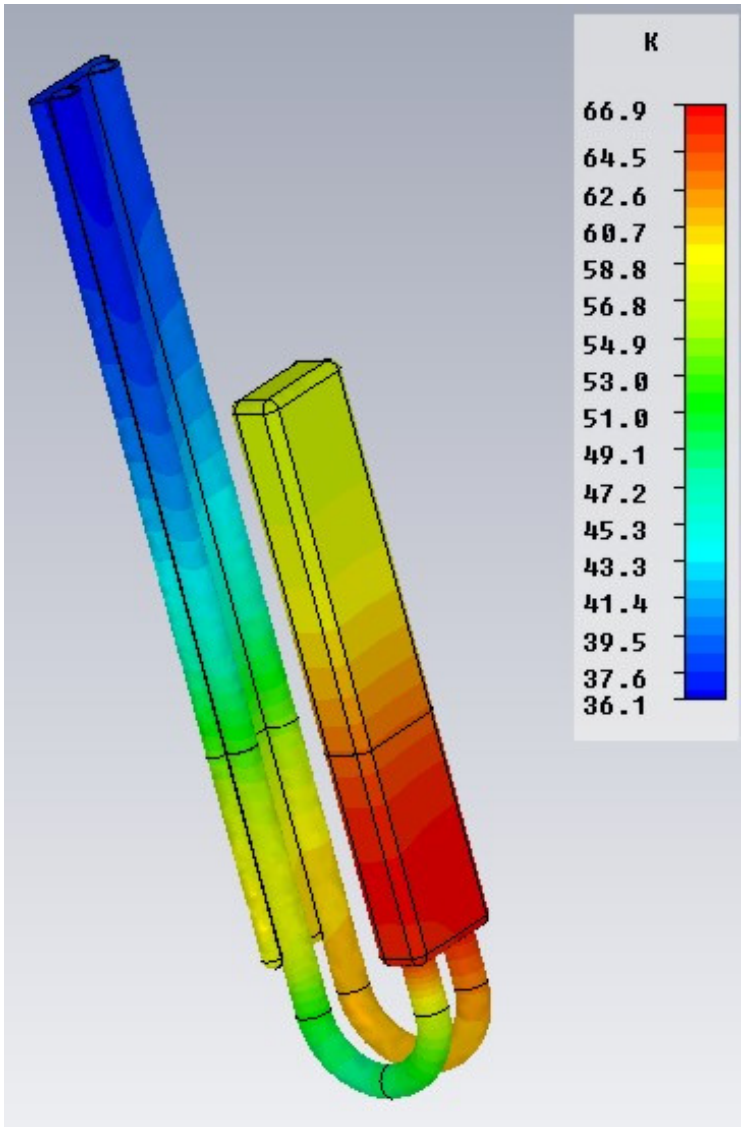
Loss in loop parts relatively to output power (S12):

C1 -37.958 dB
C2 -30.105 dB
C3 -30.944dB
C4 -37.51dB

For Pout = 50 kW the loss in loop parts:

C1 8.0 W
C2 48.8 W
C3 40.2 W
C4 8.9 W

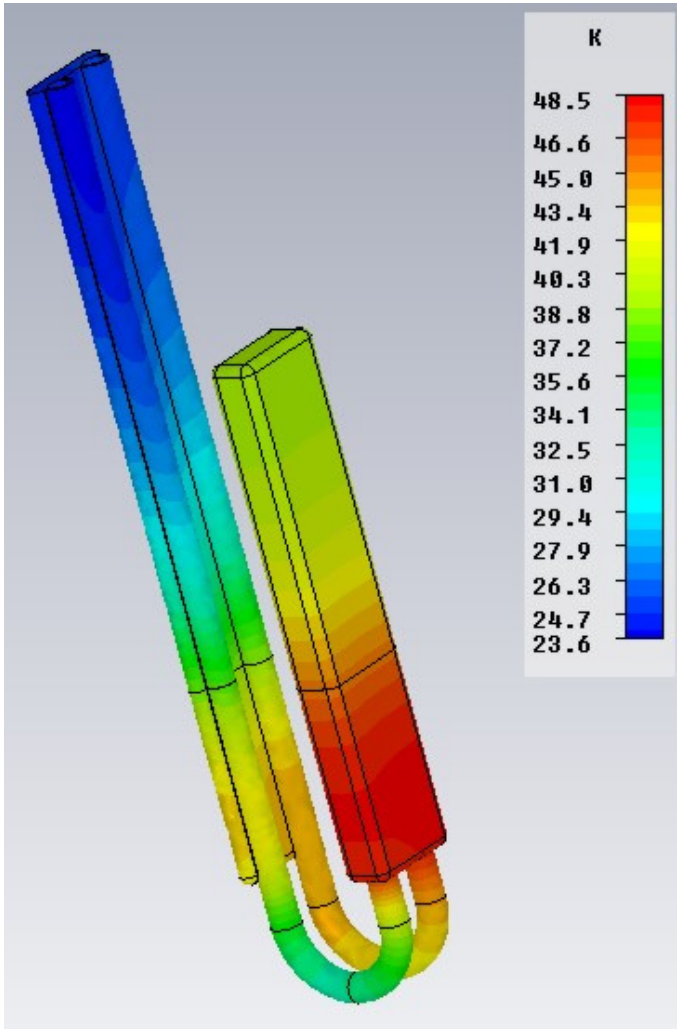
Total ~ 106 W



Air cooling

Flow rate ~ 2g/s
Convection ~ 400 W/(m2*K)
Air speed ~ 94 m/s
Pressure drop ~ 0.3bar

Temperature of input air is 0.



Air cooling

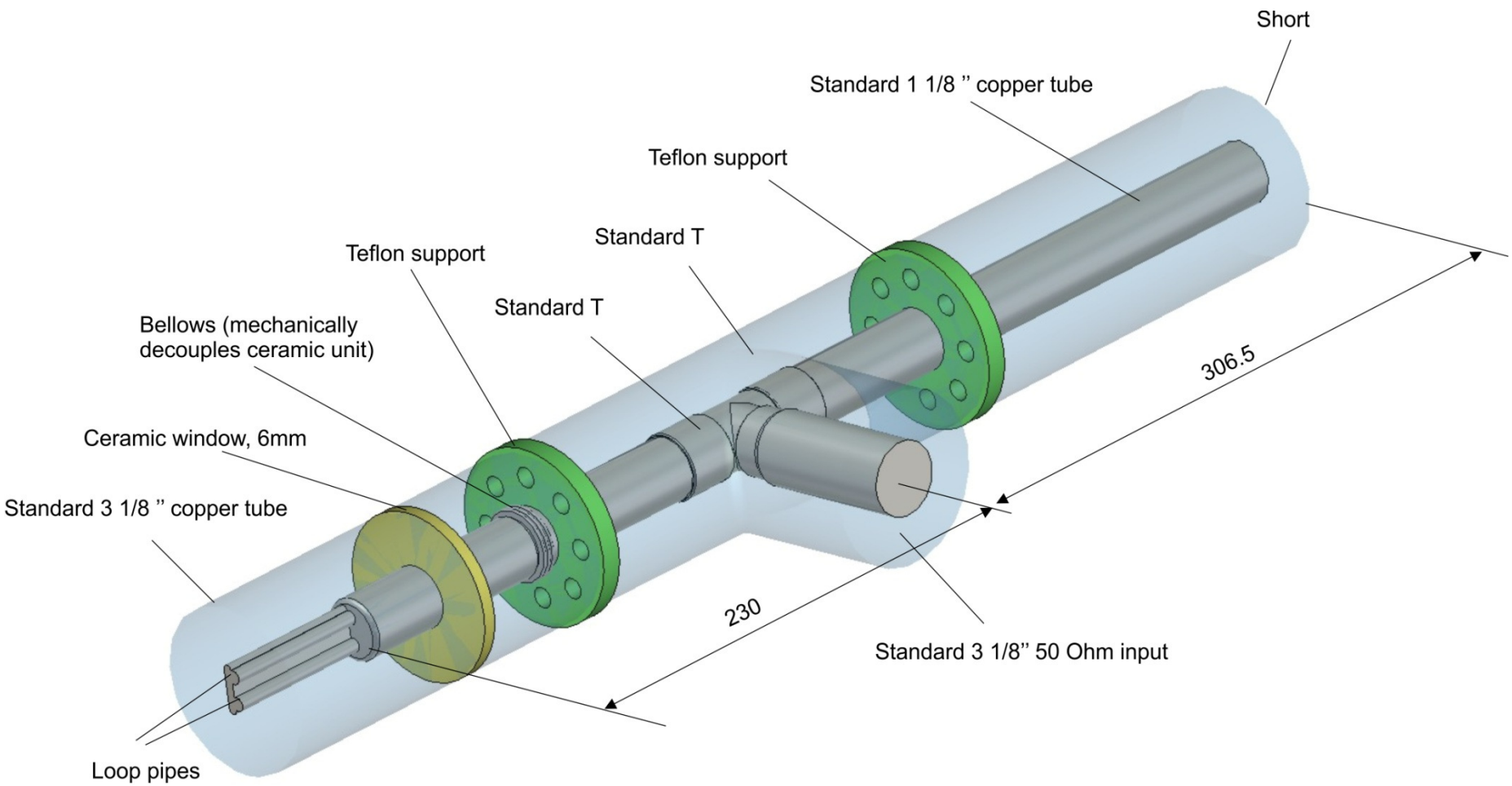
Flow rate ~ 3g/s
Convection ~ 550 W/(m2*K)
Air speed ~ 140 m/s
Pressure drop ~ 0.8bar

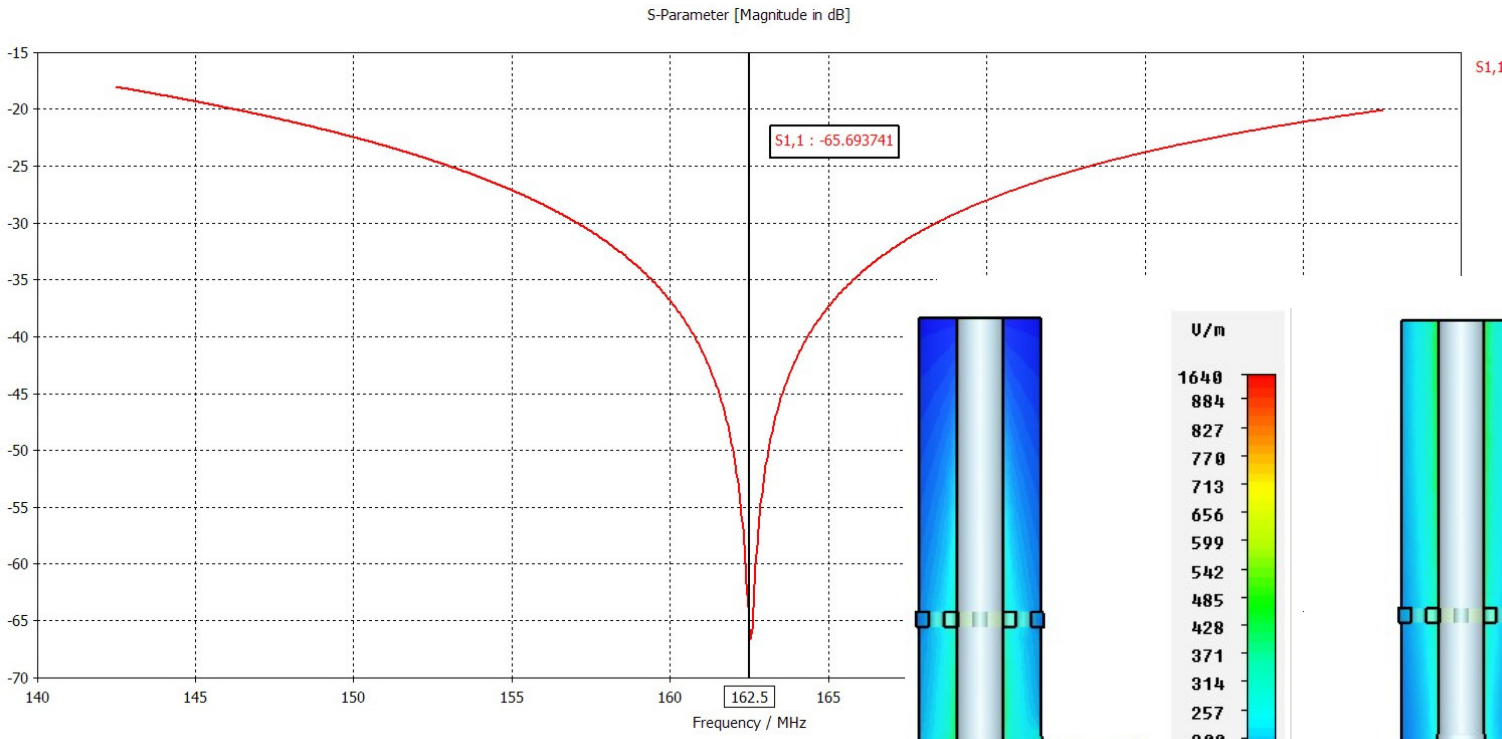
Temperature of input air is 0.

Conclusion:

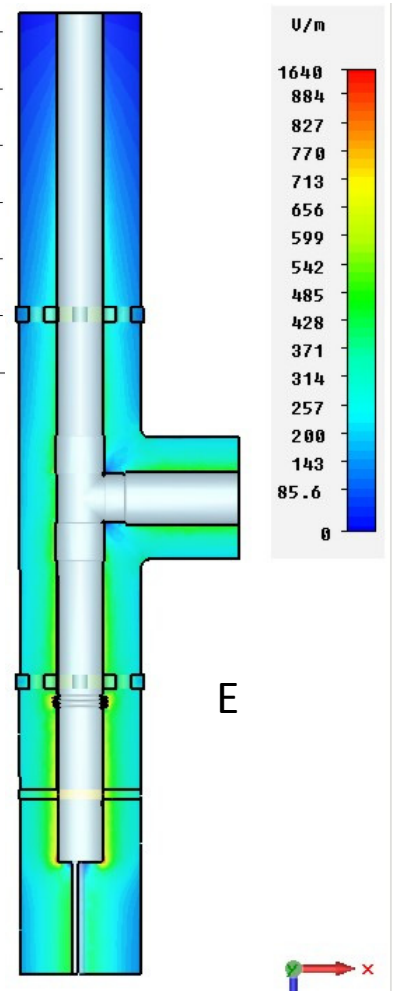
It seems 0.5 -1. bar pressure and 2-3 g/s flow are enough to cool RFQ loop/RFQ coupler

RF structure of coupler

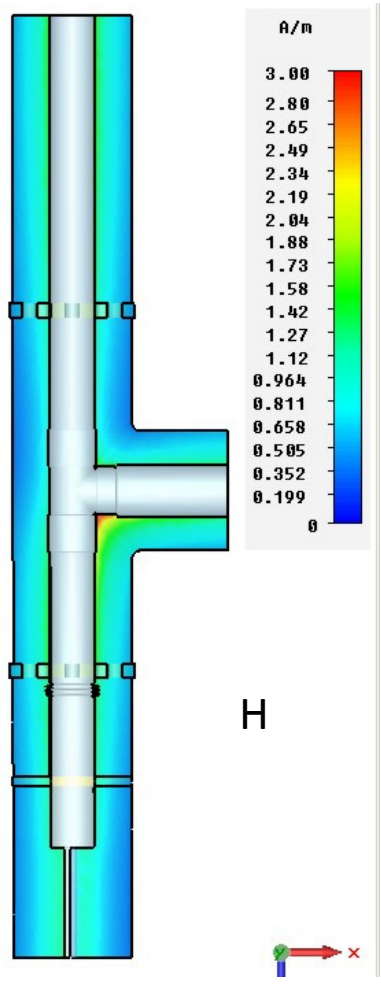



S-Parameter [Magnitude in dB]
S1,1
S1,1 : -65.693741
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-65
-70
140
145
150
155
160
162.5
165
Frequency / MHz

P = 0.5 W

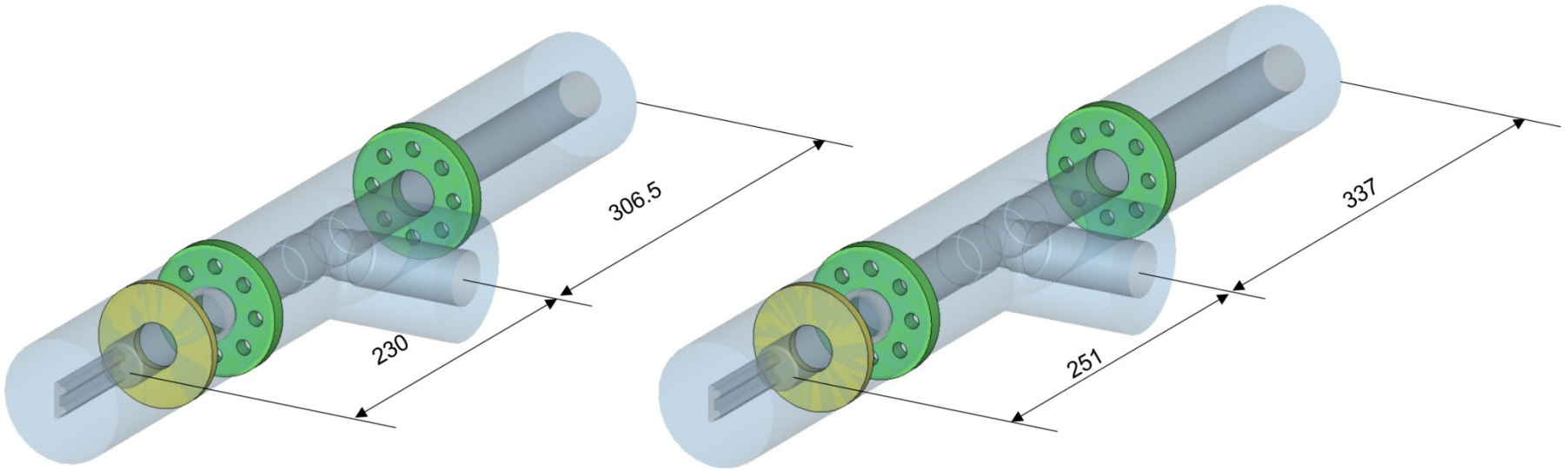

V/m
1640
884
827
770
713
656
599
542
485
428
371
314
257
200
143
85.6
0

E


A/m
3.00
2.80
2.65
2.49
2.34
2.19
2.04
1.88
1.73
1.58
1.42
1.27
1.12
0.964
0.811
0.658
0.505
0.352
0.199
0

H

Twins

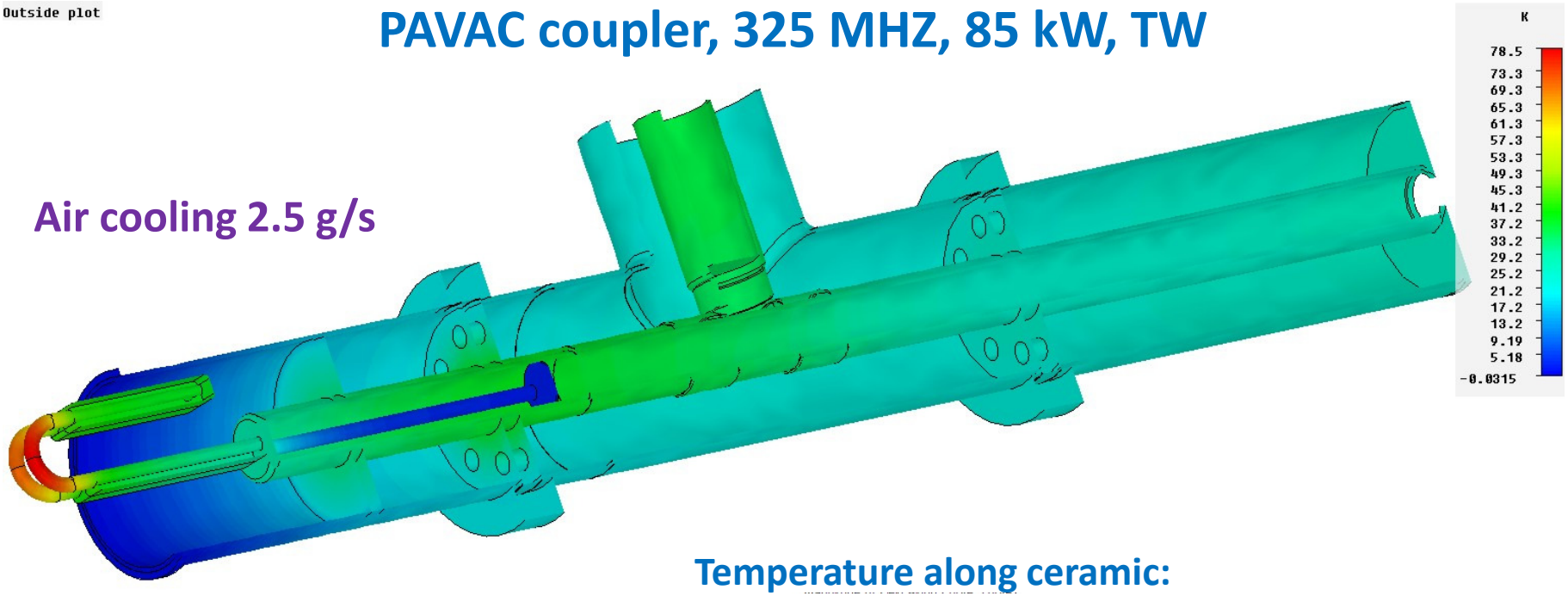


RFQ coupler
162.5 MHz, 50 kW (75 kW)

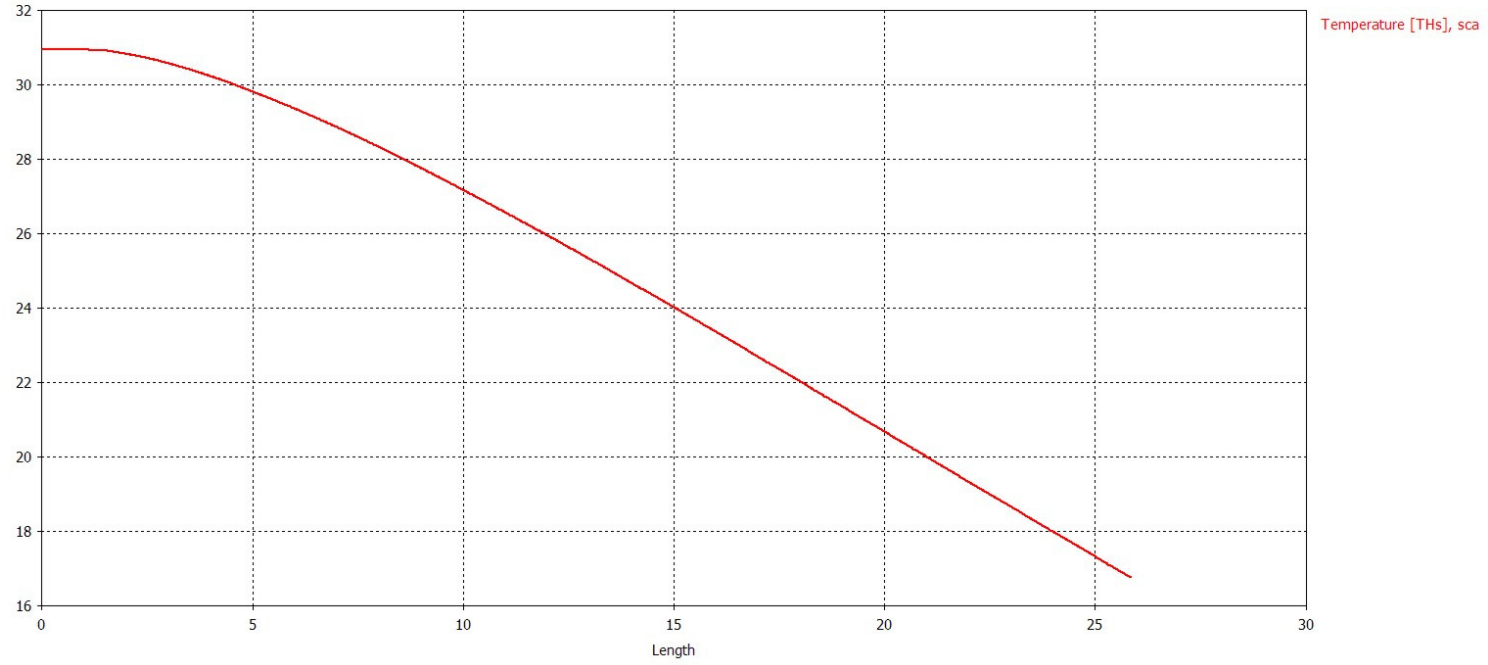
PAVAC coupler
325 MHz, 85 kW

PAVAC coupler, 325 MHZ, 85 kW, TW

Air cooling 2.5 g/s

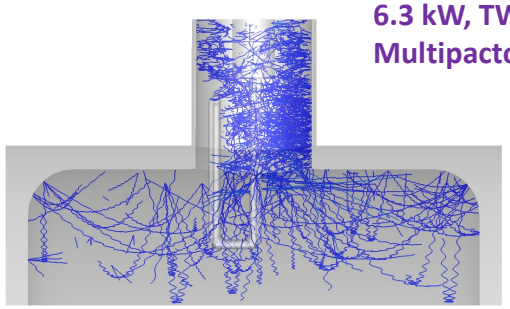


Temperature along ceramic:

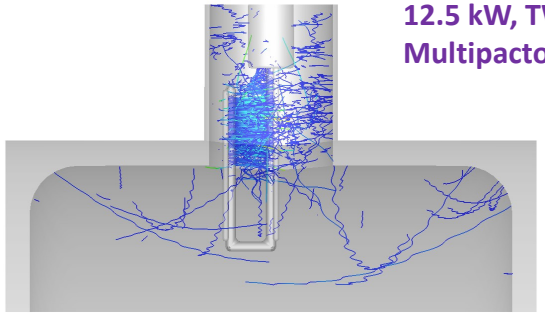


T_grad = 0.67 C/mm

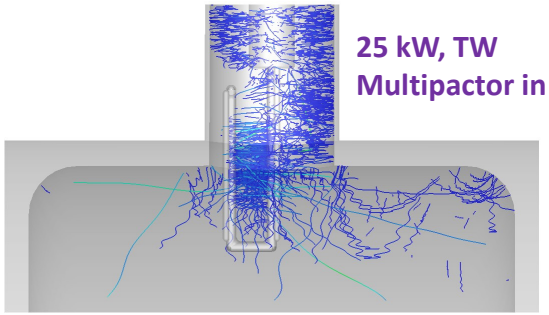
Examples of multipacor, 325 MHz coupler



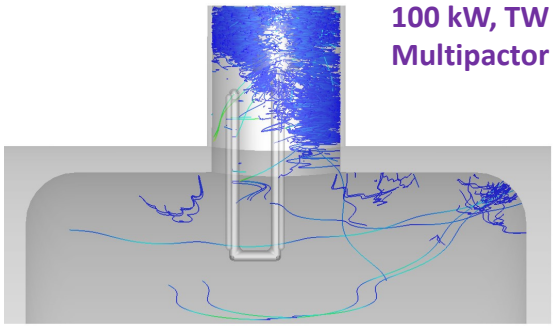
6.3 kW, TW,
Multipactor threshold



12.5 kW, TW.
Multipactor is in loop mostly



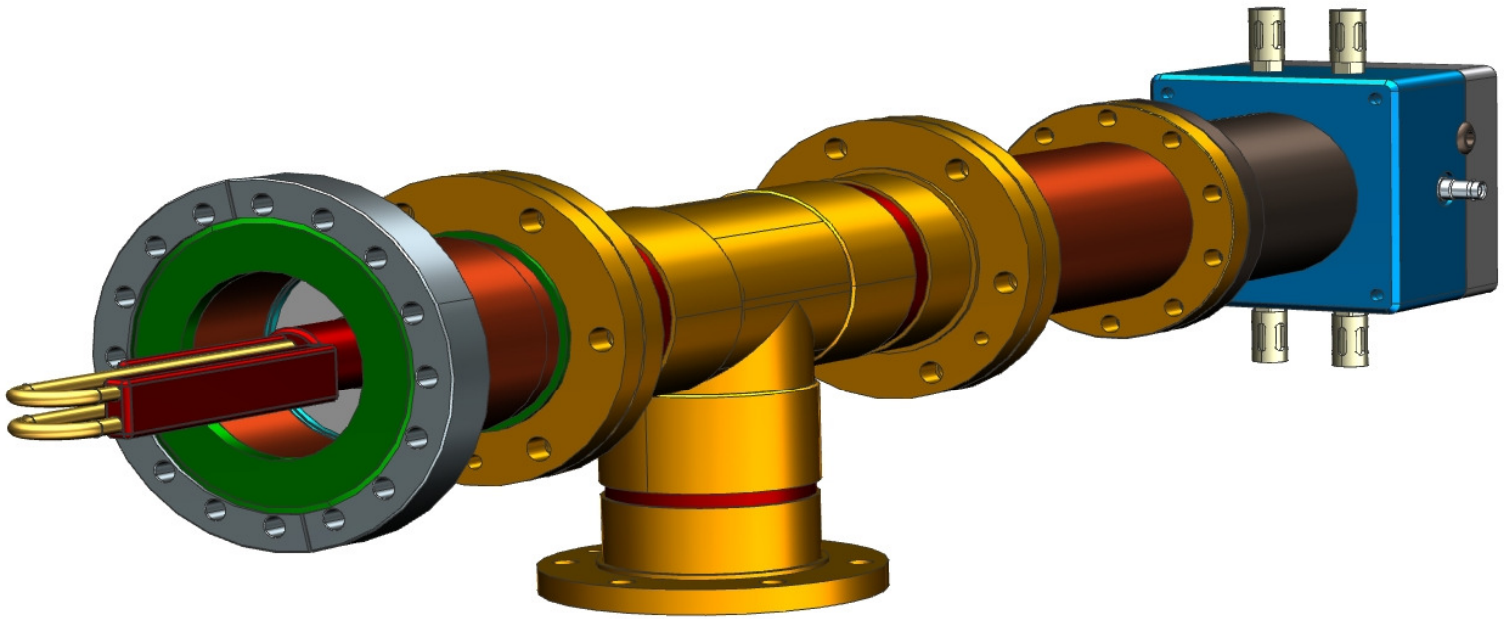
25 kW, TW
Multipactor in loop and cylinder



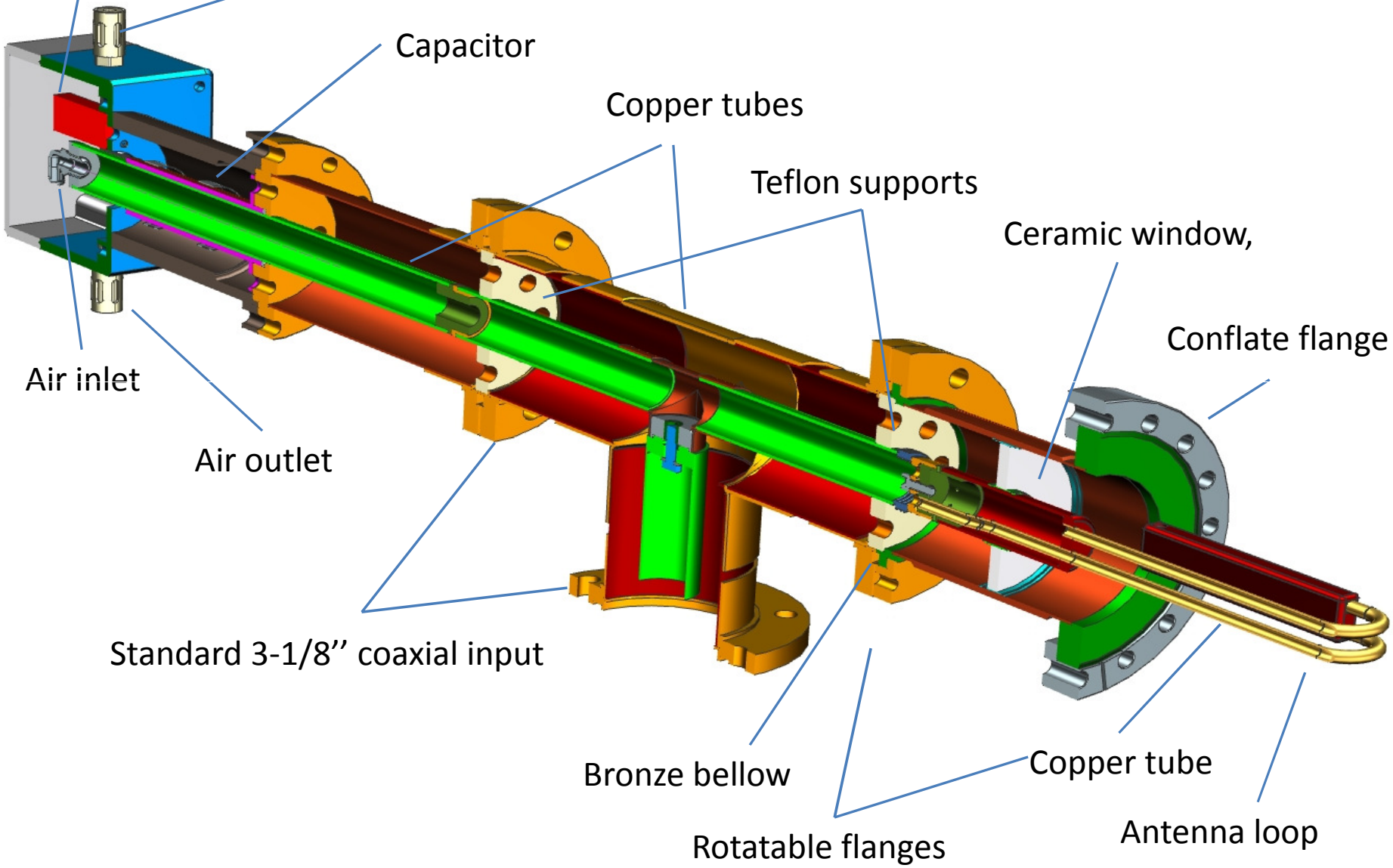
100 kW, TW
Multipactor is in cylindrical part

4 kV bias suppresses multipactor

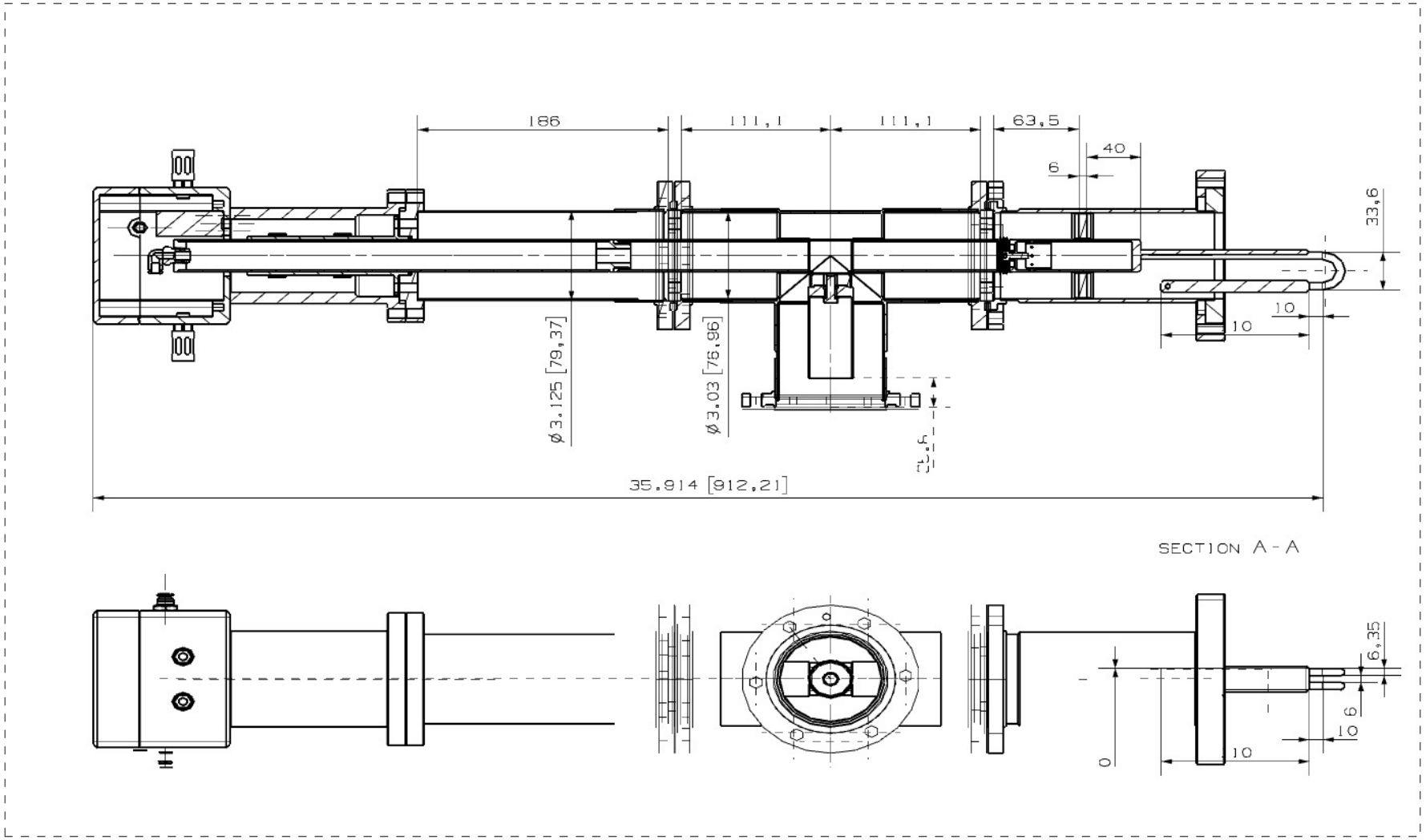
Mechanical design



Mechanical design of the coupler



162.5 MHz coupler, sizes

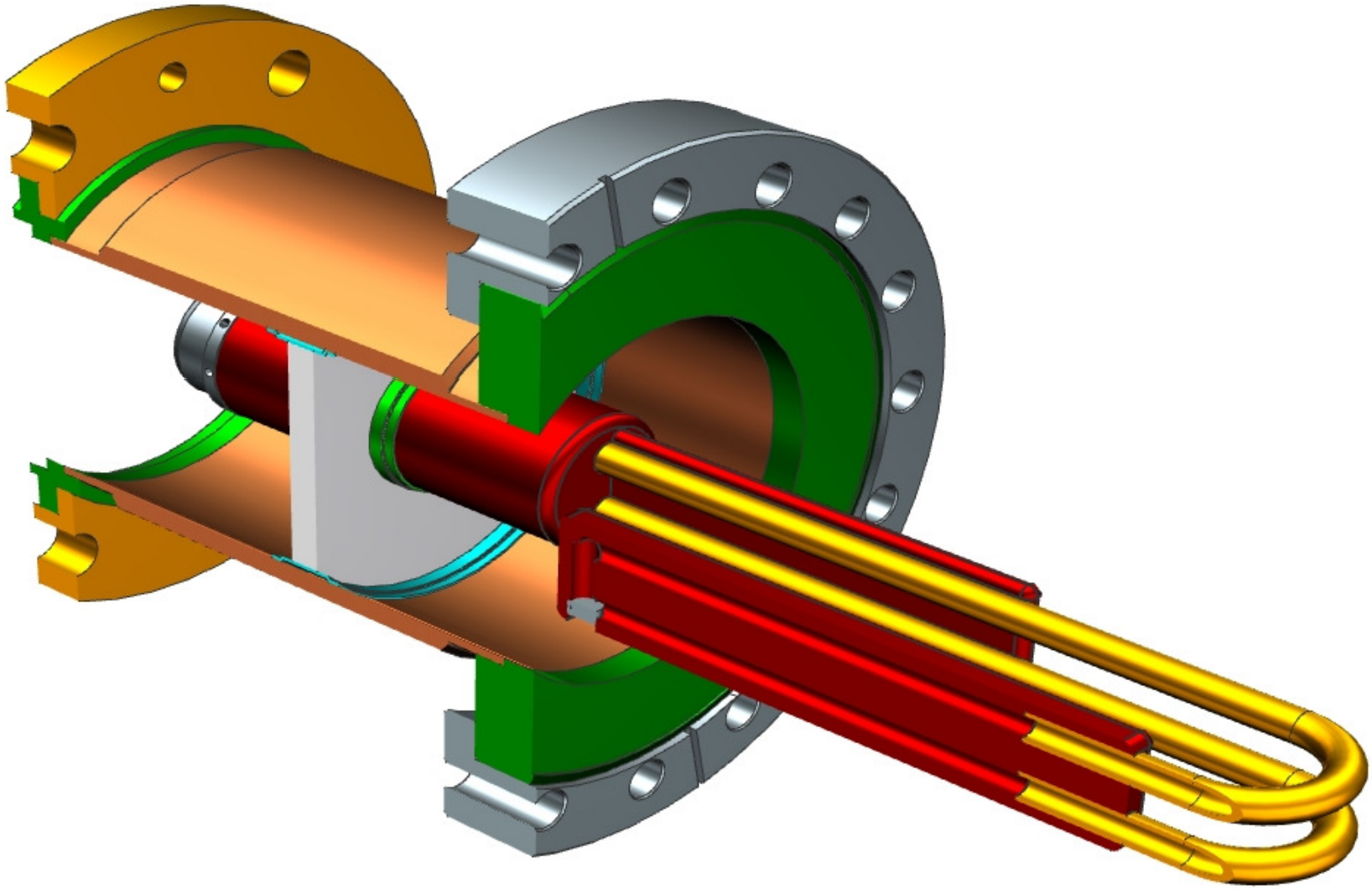


A

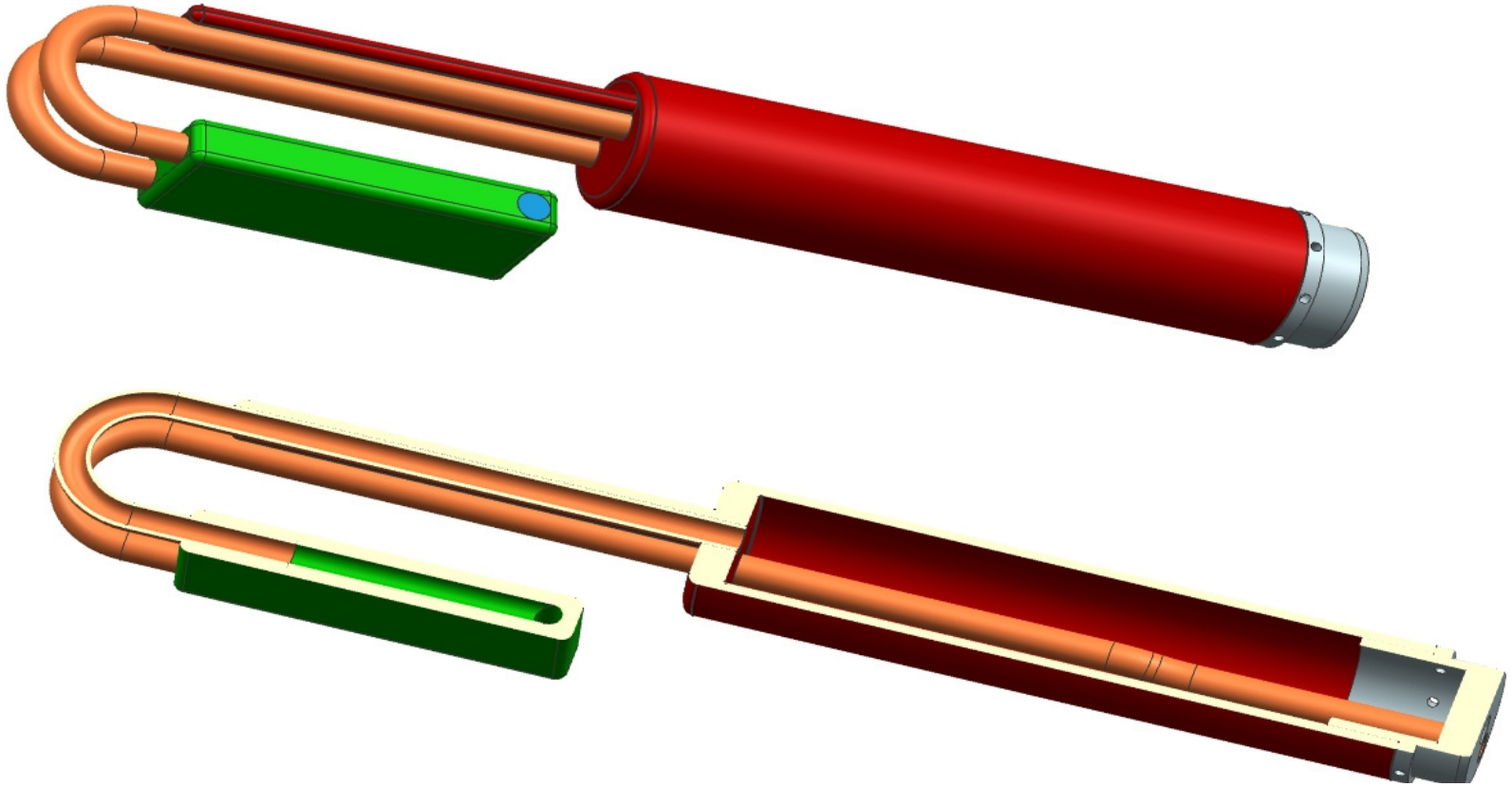
A

Sheet "Sheet 1" Work (Out of Date)

Ceramic window assembly

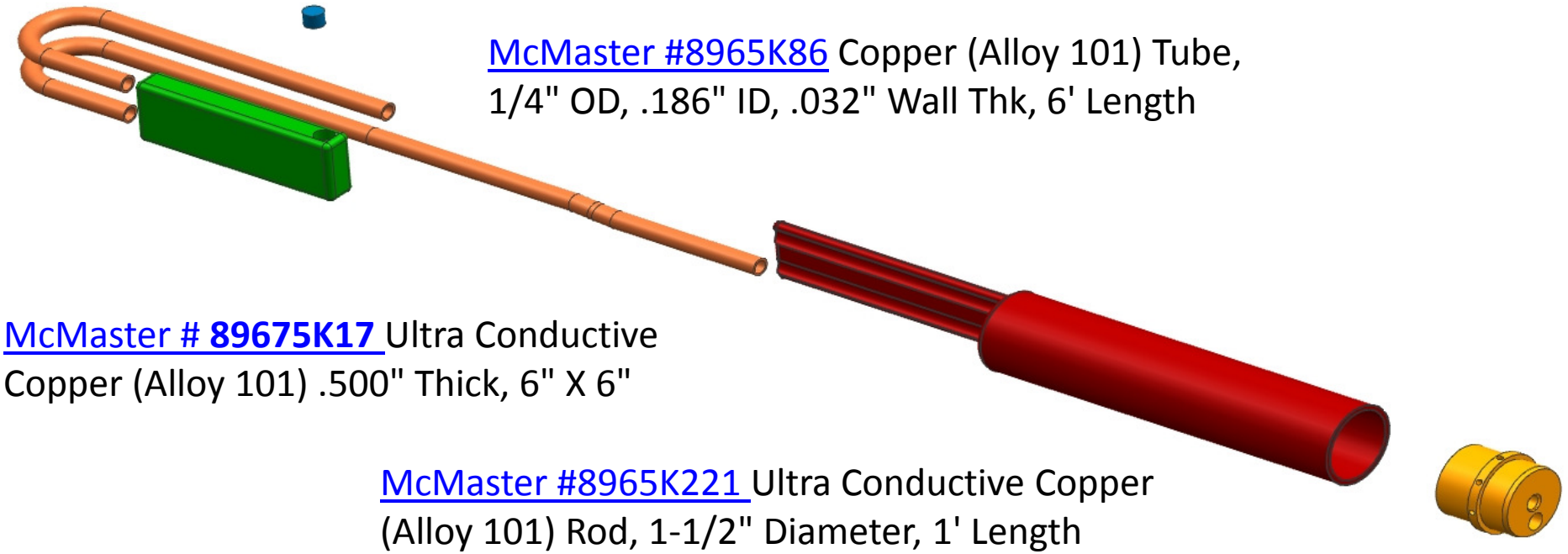


Ceramic window assembly components
Antenna End with loop



Inlet cross section surface area – 17.3 mm²
Outlet cross section surface area – 22.09 mm²

Ceramic window assembly components
Antenna End with loop



McMaster #8965K86 Copper (Alloy 101) Tube, 1/4" OD, .186" ID, .032" Wall Thk, 6' Length

McMaster # **89675K17** Ultra Conductive Copper (Alloy 101) .500" Thick, 6" X 6"

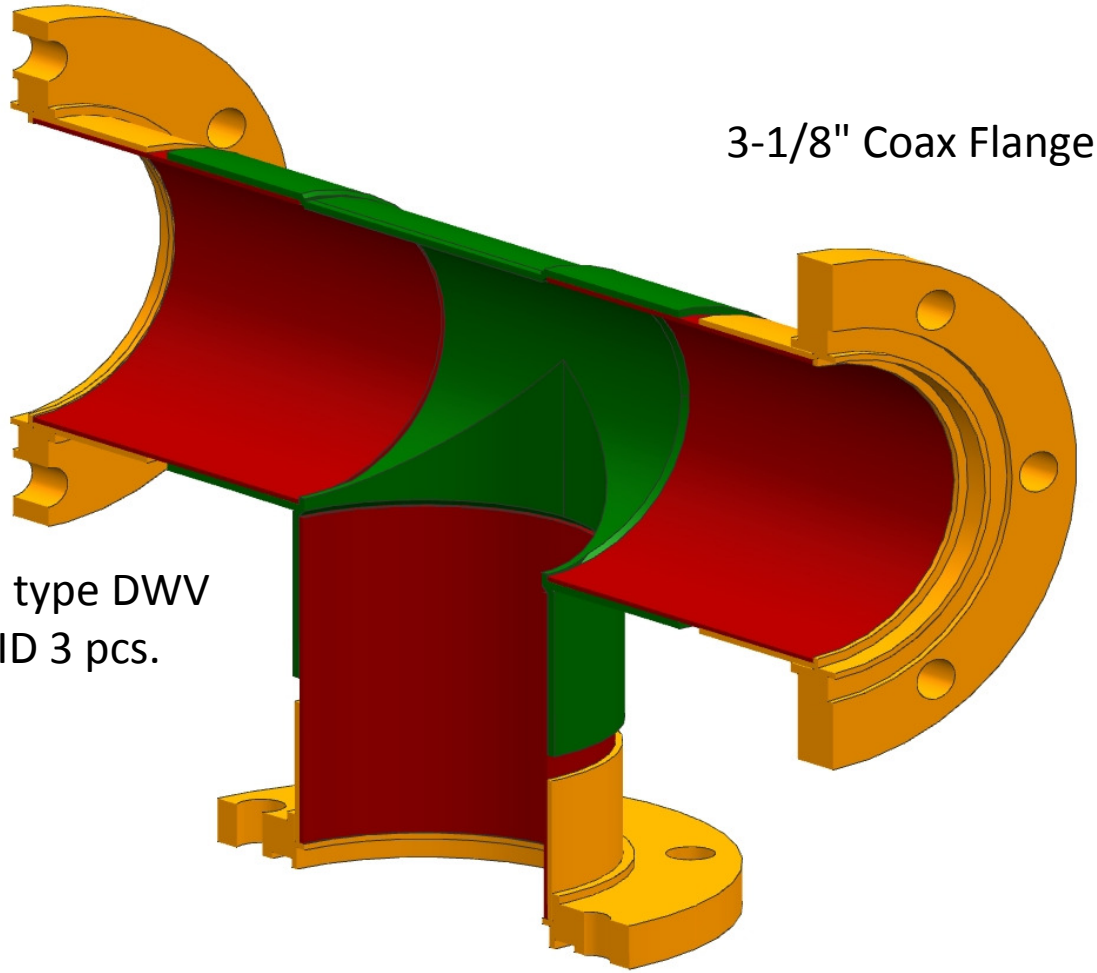
McMaster #8965K221 Ultra Conductive Copper (Alloy 101) Rod, 1-1/2" Diameter, 1' Length

McMaster #9260K54 SS (Type 316) 3" Diameter, 1-1/2" Long

Outer T-junction

McMaster#5520K835 Solder-Joint Copper 122 Tube Fitting for Water Tee, for 3" Tube Size,

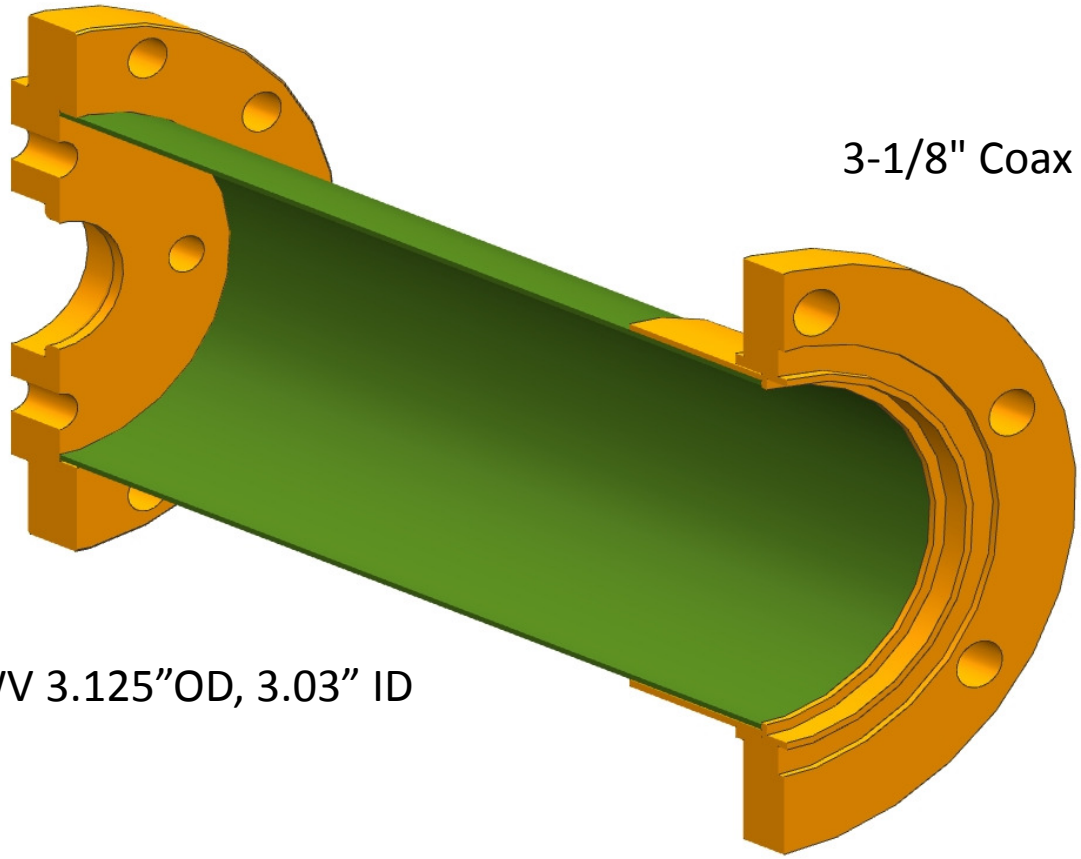
3-1/8" Coax Flange (Brass) 3pcs



Copper Tube 122 type DWV
3.125”OD, 3.03” ID 3 pcs.

Straight Outer Conductor

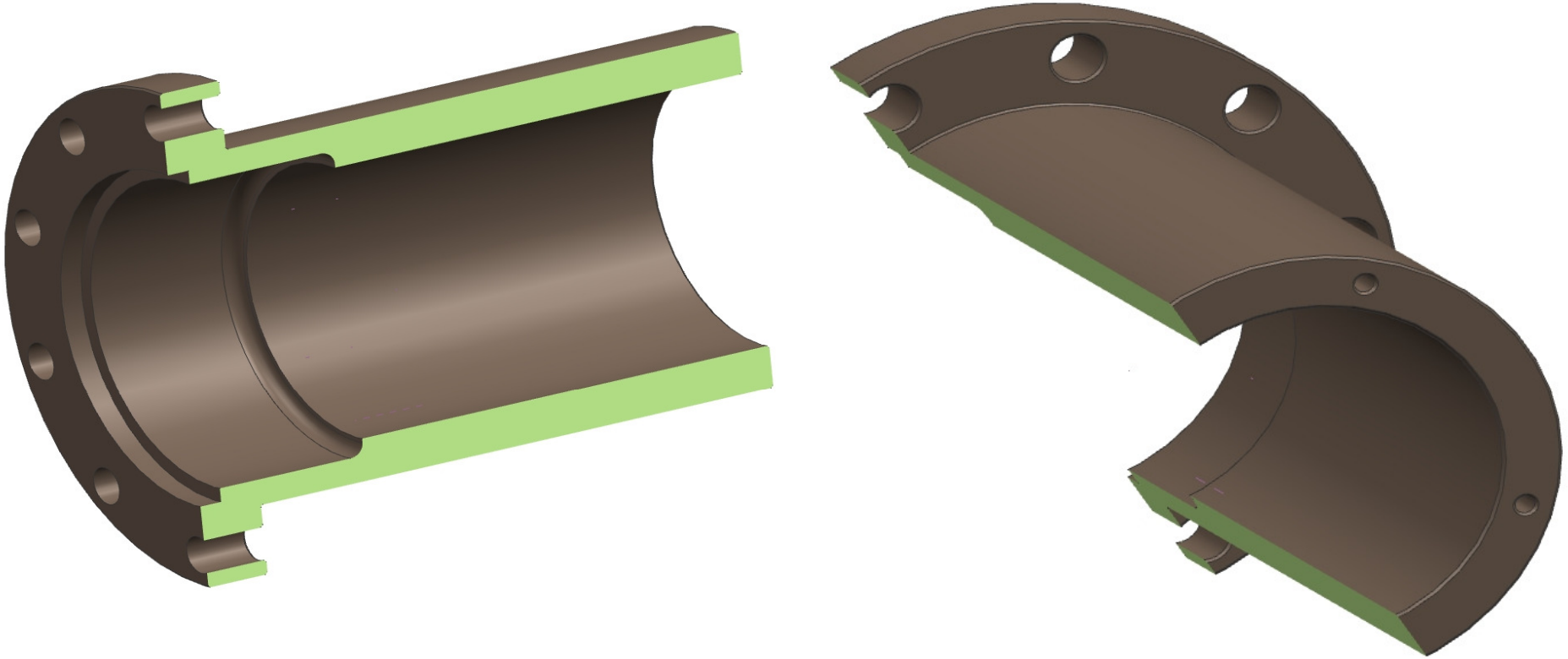
End Flange (Brass)



3-1/8" Coax Flange (Brass)

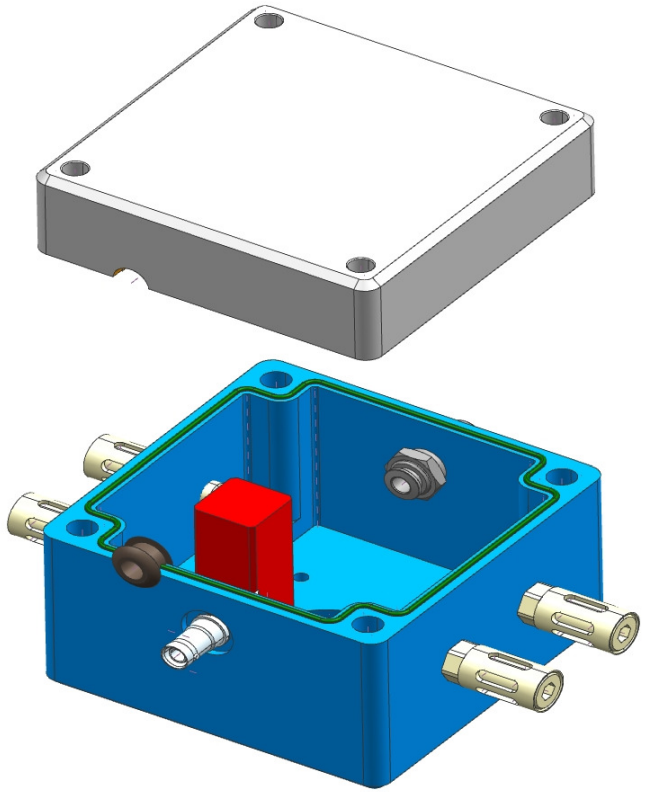
Copper Tube type DWV 3.125”OD, 3.03” ID

Outer Conductor Extension



Material: Aluminum 6061-T6

Instrumentation Box



Photosensor Hamamatsy series H10720-01

Rubber grommet, 5/16 ID Mcmaster #9600K54

Electrical feedthrough Kings #1704-01

Airline feedthrough Festo#QSS-1/4T-U

Silencer Festo#U-1/8-B-NPT

McMaster#75895K15Alum Enclosure (NEMA 4X) Screw Cover, 4.8" Height X 4.8" Width X 4" Depth

Straight Inner Conductor

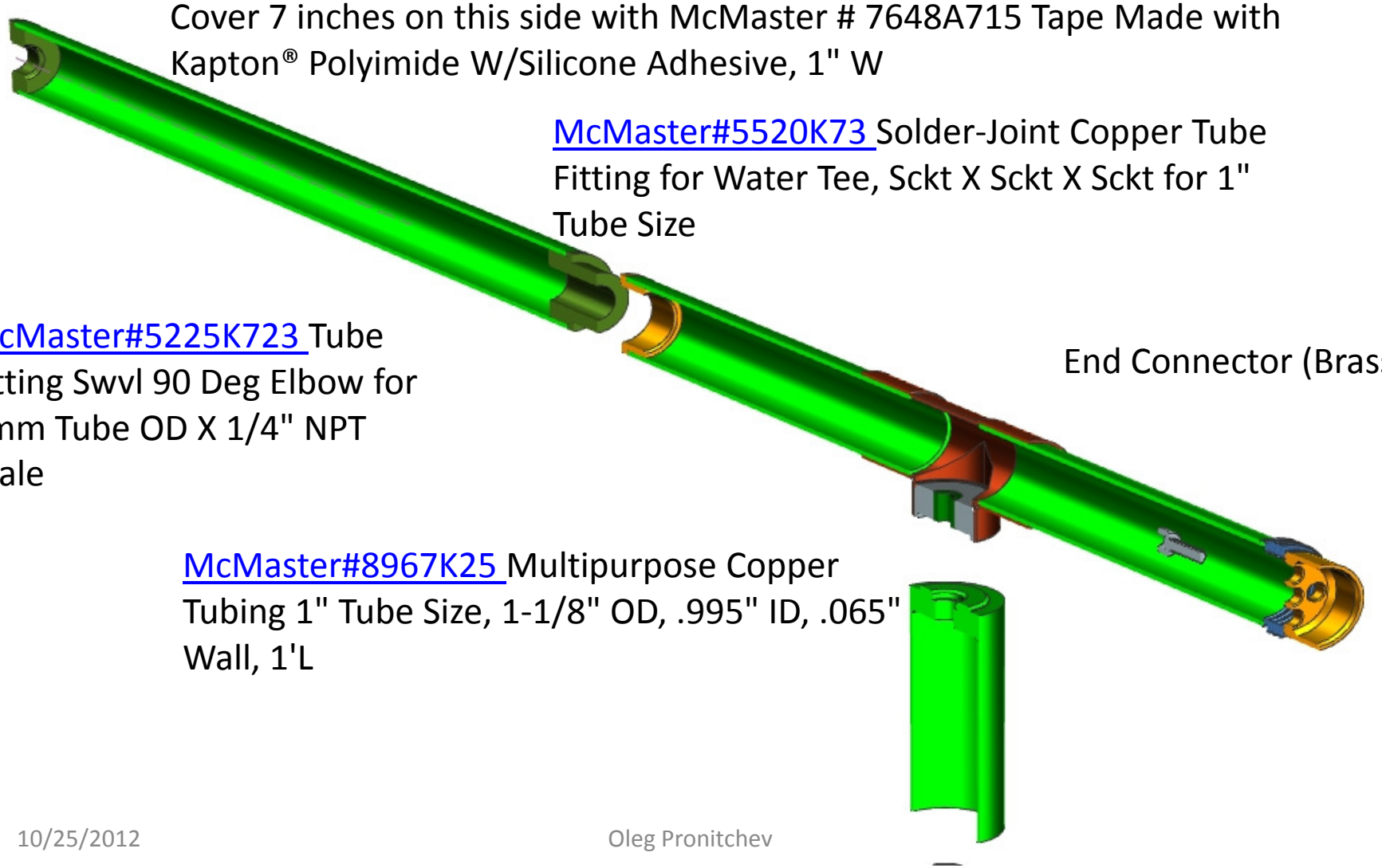
Threaded adapter (Brass or SS316)

Cover 7 inches on this side with McMaster # 7648A715 Tape Made with Kapton® Polyimide W/Silicone Adhesive, 1" W

McMaster#5520K73 Solder-Joint Copper Tube Fitting for Water Tee, Sckt X Sckt X Sckt for 1" Tube Size

McMaster#5225K723 Tube Fitting Swvl 90 Deg Elbow for 6mm Tube OD X 1/4" NPT Male

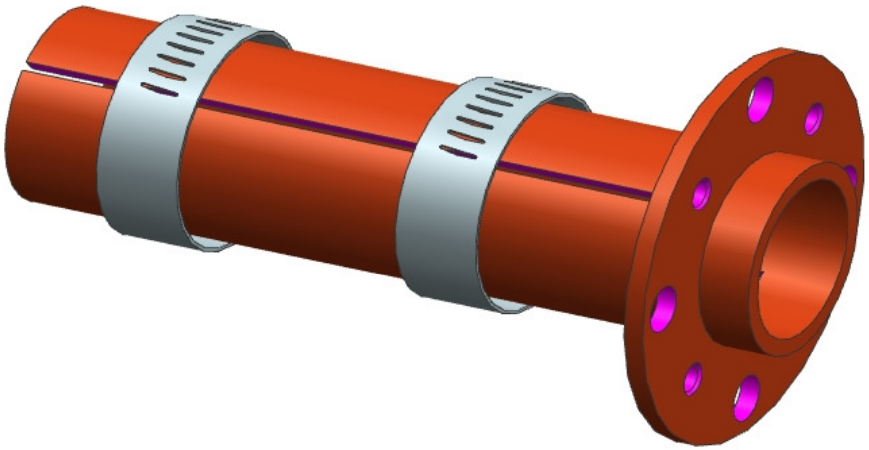
End Connector (Brass)

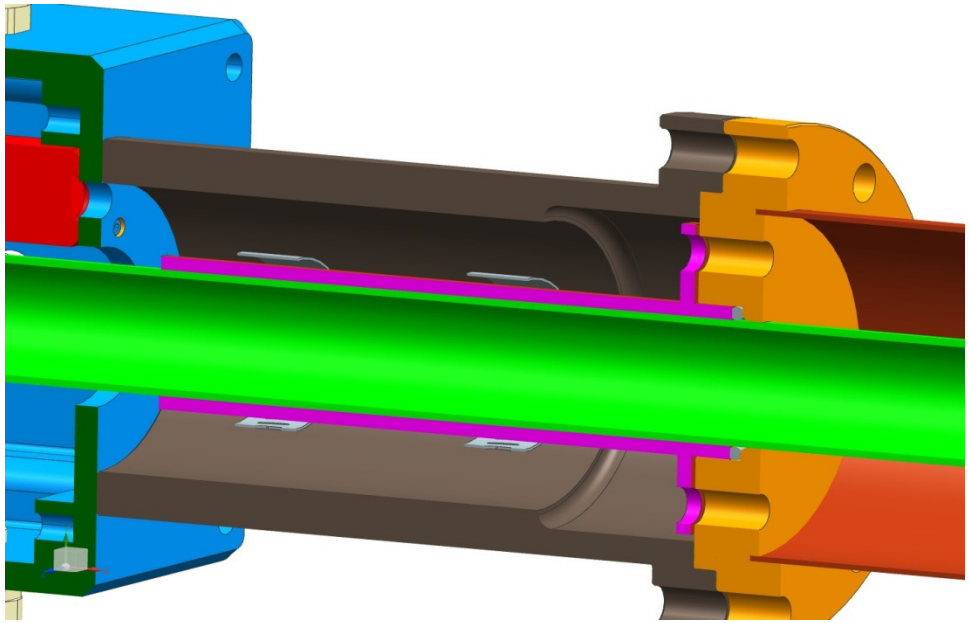


McMaster#8967K25 Multipurpose Copper Tubing 1" Tube Size, 1-1/8" OD, .995" ID, .065" Wall, 1'L

Capacitor with conductor ring

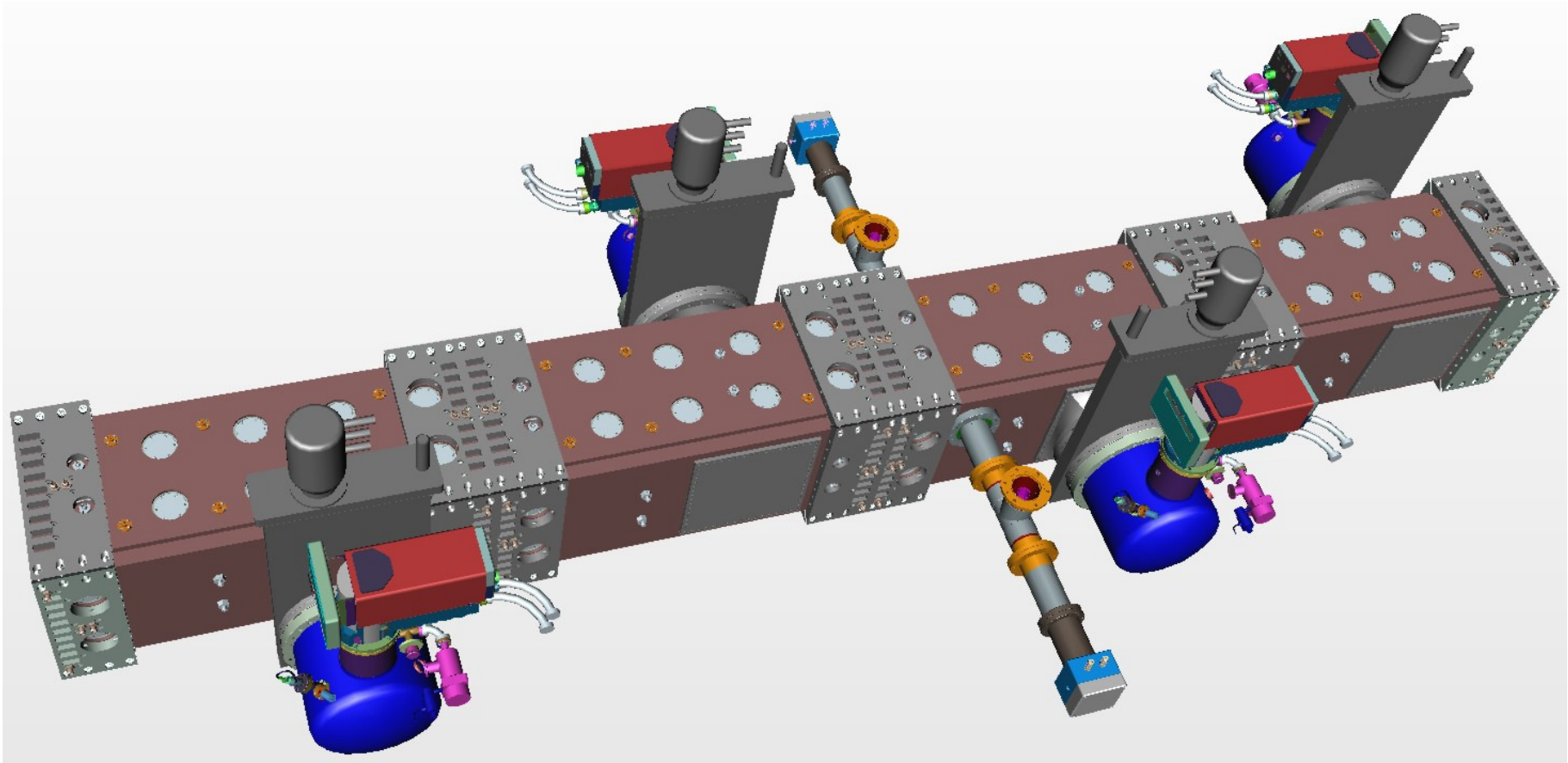
Material: Copper 122

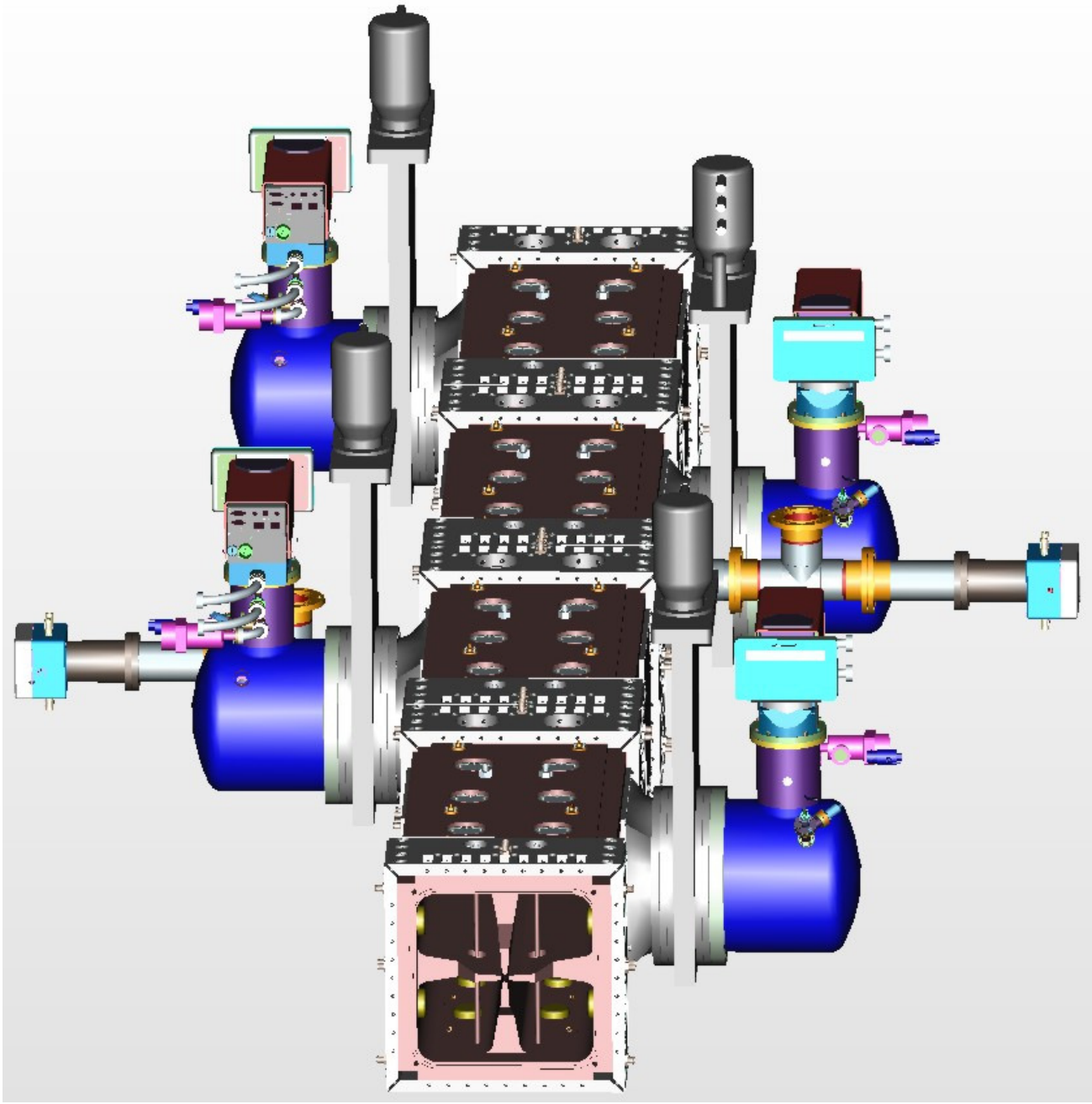


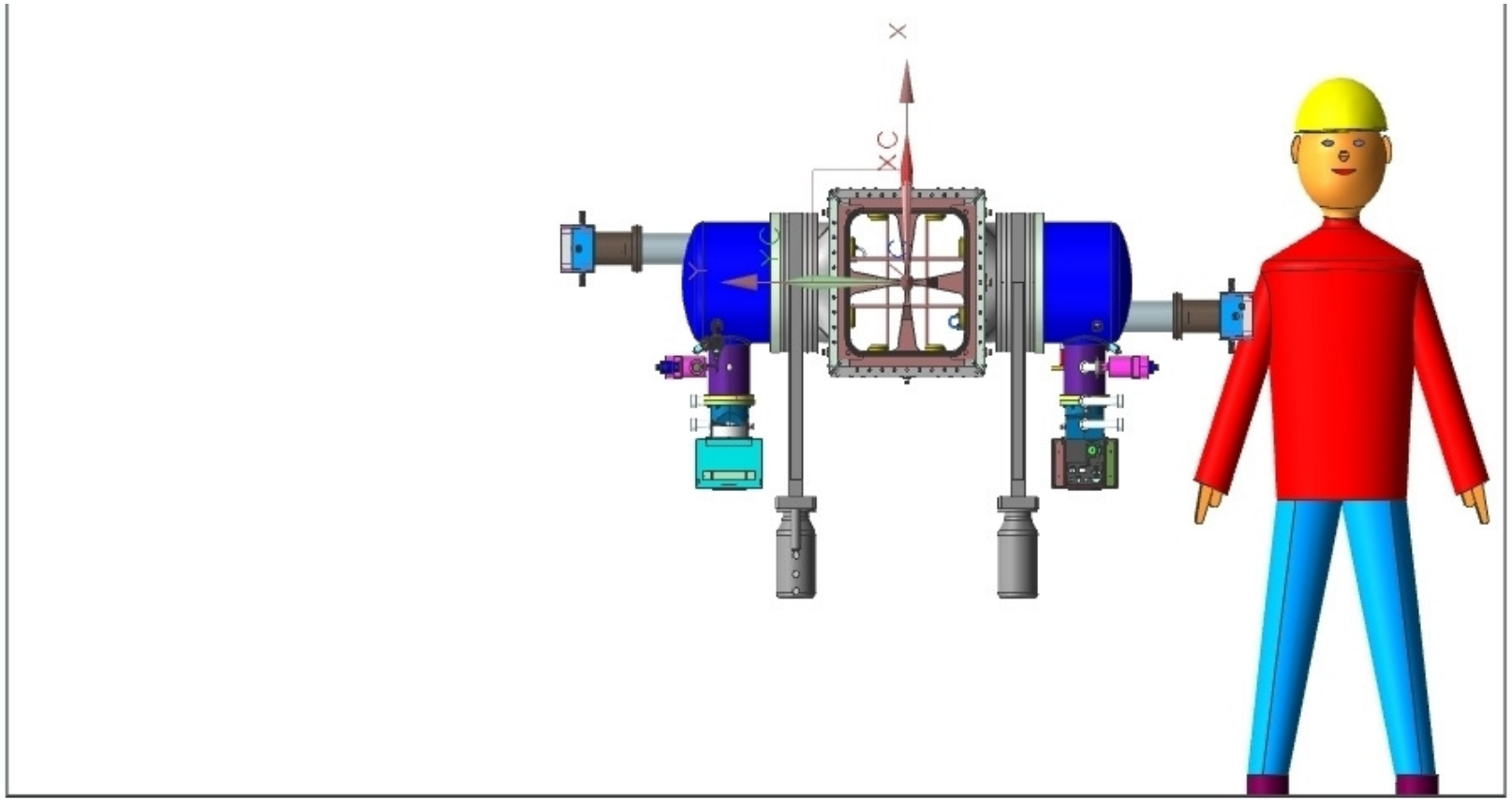


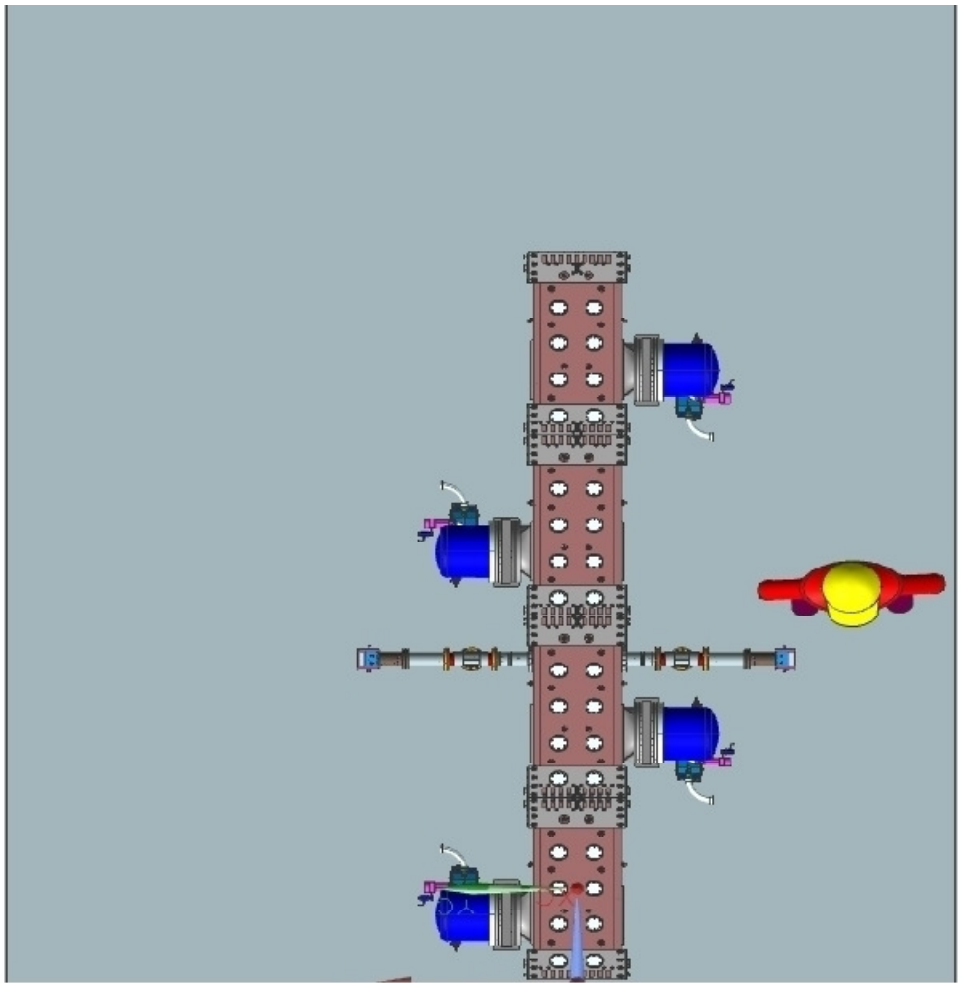
McMster#5416K16

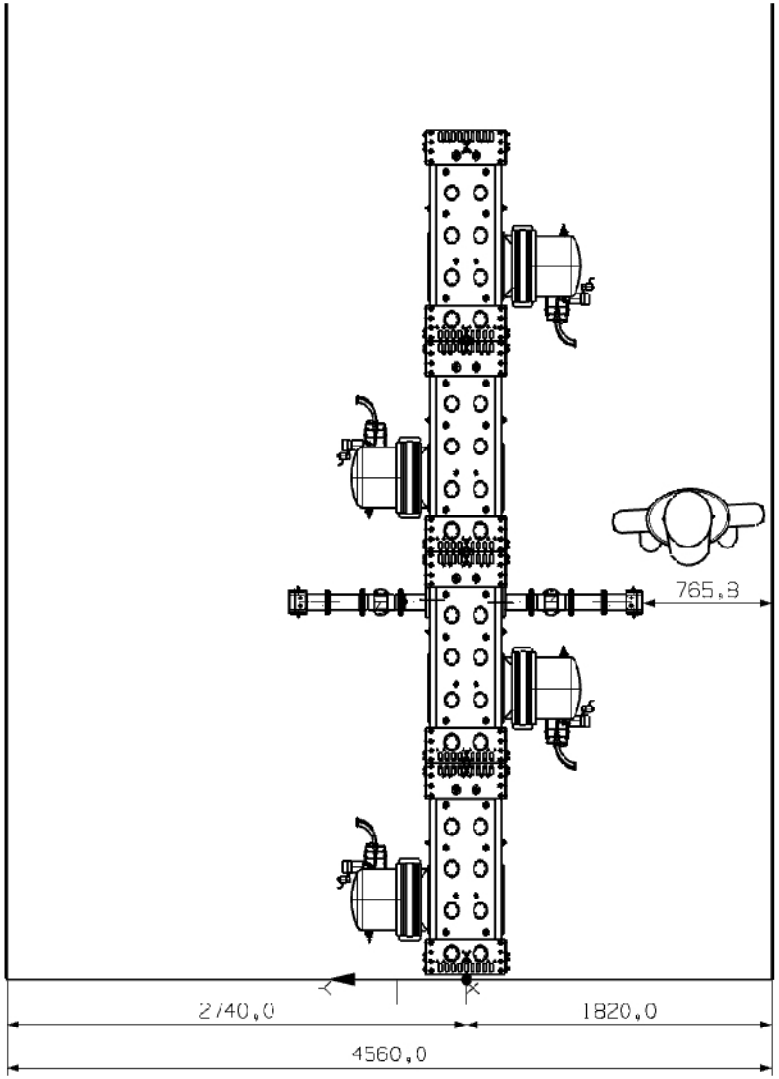
Worm-Drive Hose & Tube Clamp






X
XC
YC
Y




765,3
2740,0
1820,0
4560,0

What to do:

- Detailed thermal analyzes of 162.5 MHz coupler
- Stress analyzes
- Multipactor analyses
- Mechanical drawings
- Production of prototype(s)
- Design and build test equipment
- High power test